ALTITUDE PHYSIOLOGY

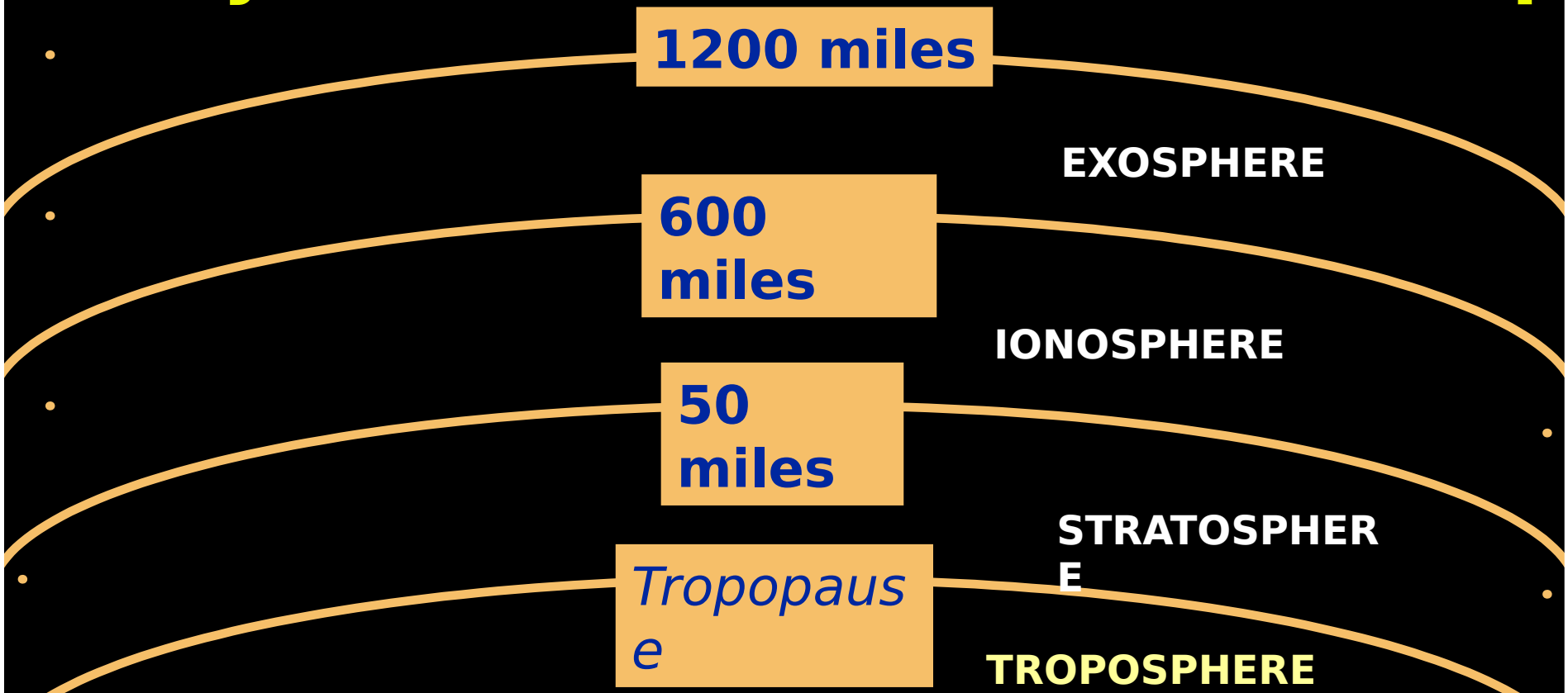
TERMINAL LEARNING OBJECTIVE

- Action: Manage the physiological effects of altitude
- Condition: While performing as an aircrew member
- Standard: IAW AR 95-1, AR 40-8, FM 3-04.301, Fundamentals of Aerospace Medicine

ELO #1

- **ACTION**: Identify the physiological zones and the physical divisions of the atmosphere.
- **CONDITION**: Given a list.
- **STANDARD**: IAW FM 3-04.301.

Physical Divisions of the Atmosp



Physiological Zones of the Atmosphere

63,000 ft

SPACE EQUIVALENT ZONE: 50,000 feet and above

50,000

DEFICIENT ZONE: 10,000 to 50,000 feet

18,000 ft

10,000

EFFICIENT ZONE: Sea level to 10,000 feet

Composition of the Air

78 % Nitrogen (N_2)

21 % Oxygen (O_2)

1 % Other

(.03 % CO_2)

Questions ???

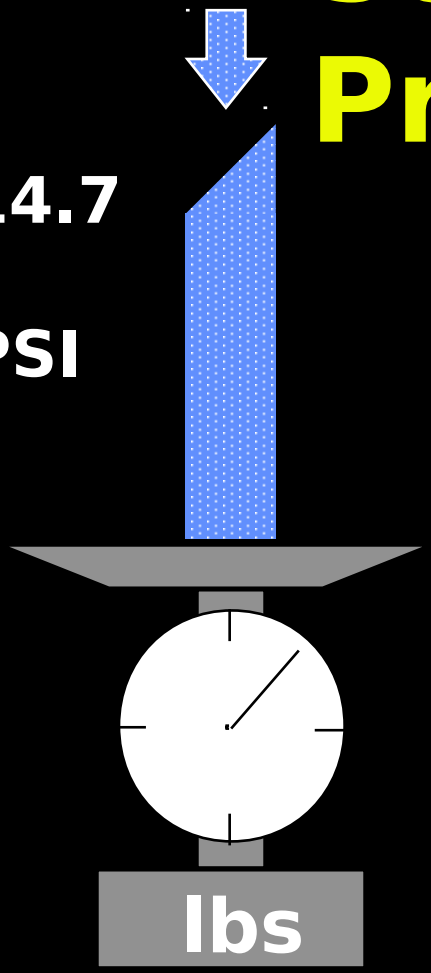
ELO #1
Check On Learning

- **Atmosphere**
- **Physiological Zones of the Atmosphere**
- **Composition of the air**

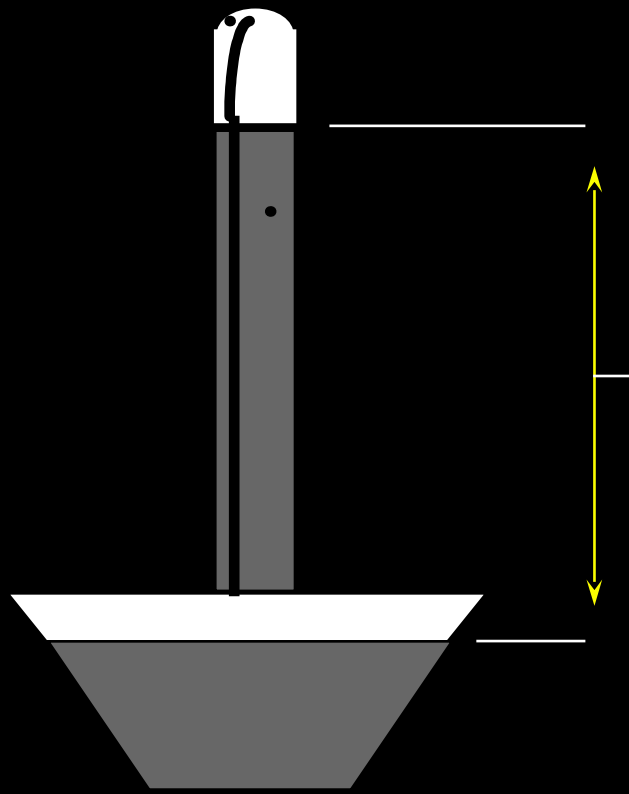
ELO #2

- **ACTION**: Select the correct barometric pressure at sea level.
- **CONDITION**: Given a list.
- **STANDARD**: IAW FM 3-04.301

Sea Level Pressure



Scale



Barometer / *Altimeter*

PERCENT COMPOSITION OF THE ATMOSPHERE REMAINS

CONSTANT

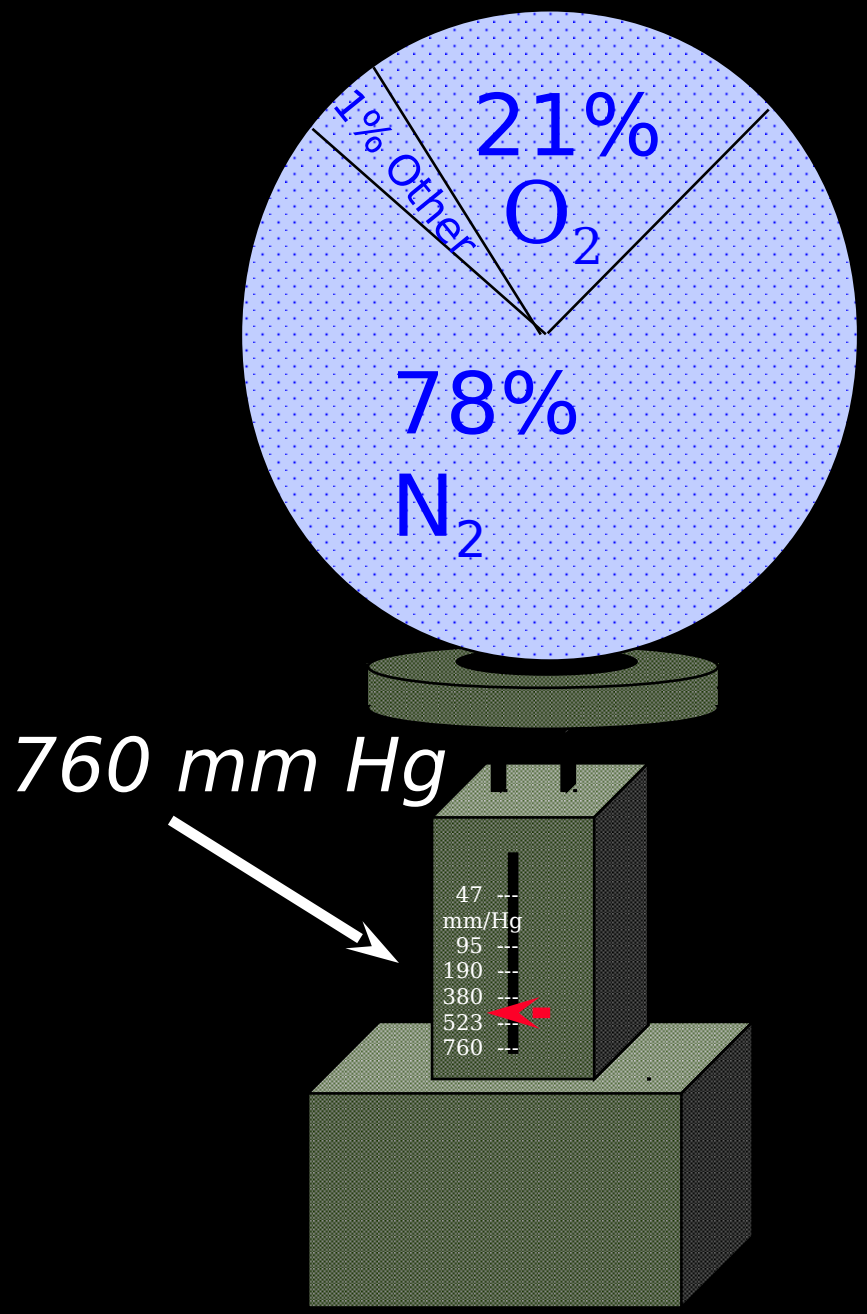
BUT PRESSURE

DECREASES

WITH ALTITUDE

SIGNIFICANT PRESSURE ALTITUDES

ALTITUDE	PRESSURE	
FEET	mm/HG	ATMOSPHERES
0	760	1
18,000	380	1/2
34,000	190	1/4
48,000	95	1/8
63,000	47	1/16



Partial Pressure (Dalton's Law)

(Dalton's Law)

The pressure exerted by a mixture of gases is equal to the sum of the partial pressures of each gas in the mixture.

$$P_t = P_1 + P_2 + \ldots + P_n$$

Questions!!

Check on Learning #2

- Atmospherics (barometric) pressure
- Dalton’s Law of partial pressure

ELO #3

- **ACTION**: Identify the components of the circulatory system that transport oxygen throughout the human body.
- **CONDITION**: Given a list.
- **STANDARD**: IAW FM 3-04.301.

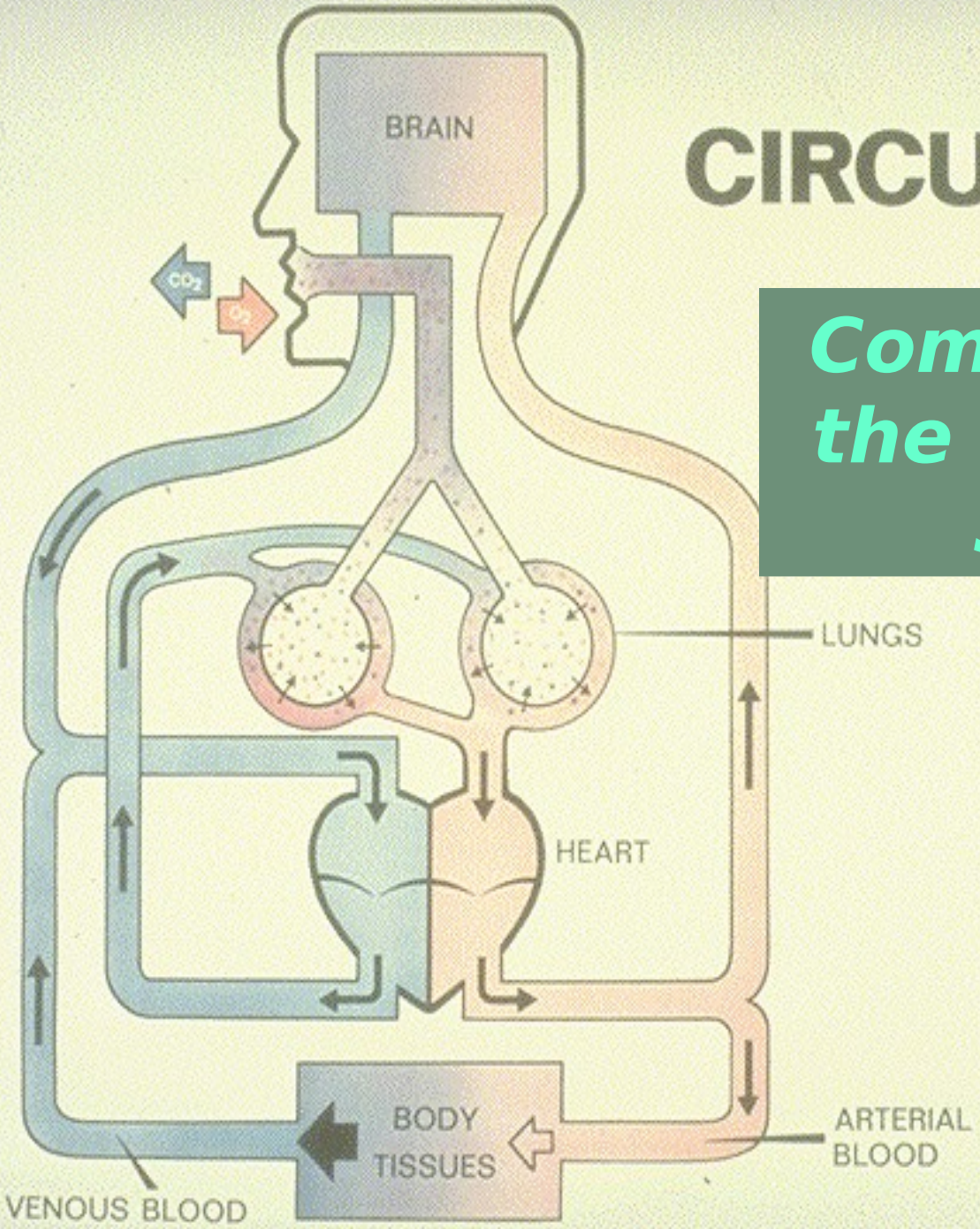
CIRCULATION

FUNCTIONS OF THE CIRCULATORY SYSTEM

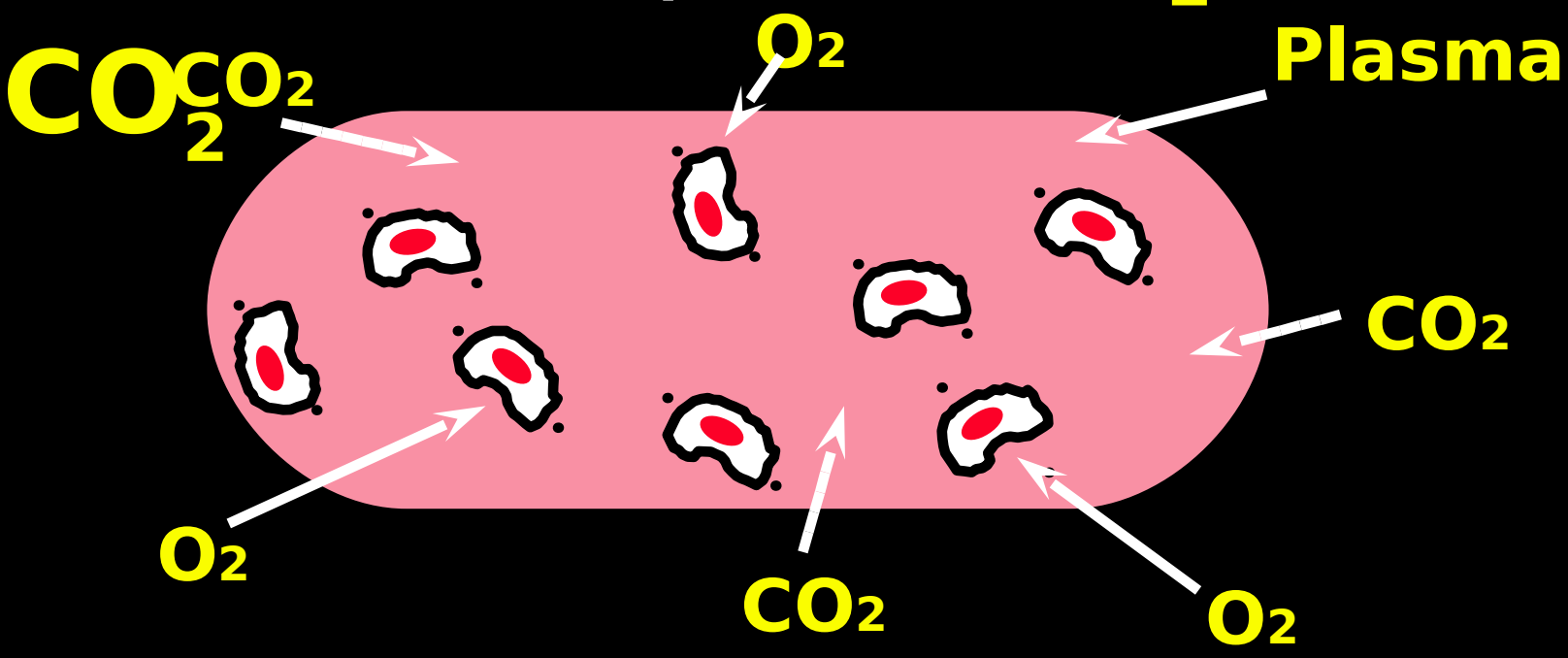
- Oxygen and nutrient (fuel) transport to the cells.
- Transport of metabolic waste products to organ removal sites.
- Assists in temperature regulation.

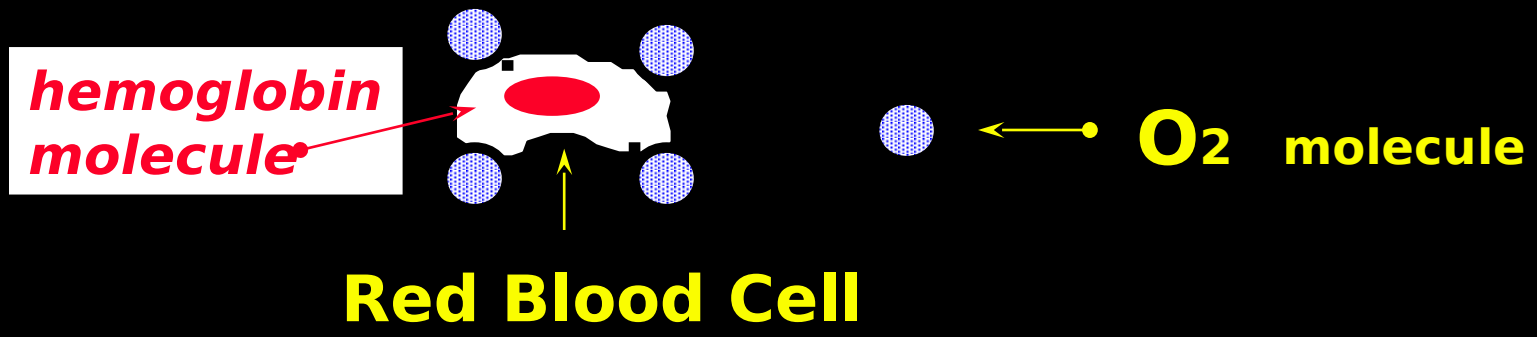
CIRCULATION

Components of the Circulatory System



Blood transport of O_2 and CO_2





QUESTIONS?

Check on Learning #3

- Functions of the circulatory systems
- Components of the circulatory systems

ELO #4

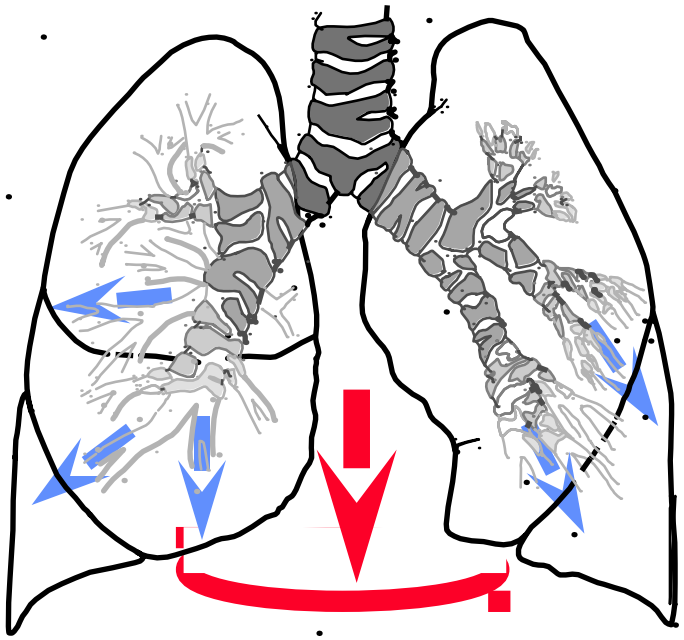
- **ACTION**: Select the functions and types of respiration.
- **CONDITION**: Given a list.
- **STANDARDS**: IAW FM 3-04.301.

FUNCTIONS OF THE RESPIRATORY SYSTEM

- ✔ Intake of Oxygen [O_2]
- ✔ Removal of Carbon Dioxide [CO_2]
- ✔ Maintenance of body heat balance
- ✔ Maintenance of body acid base balance [pH]

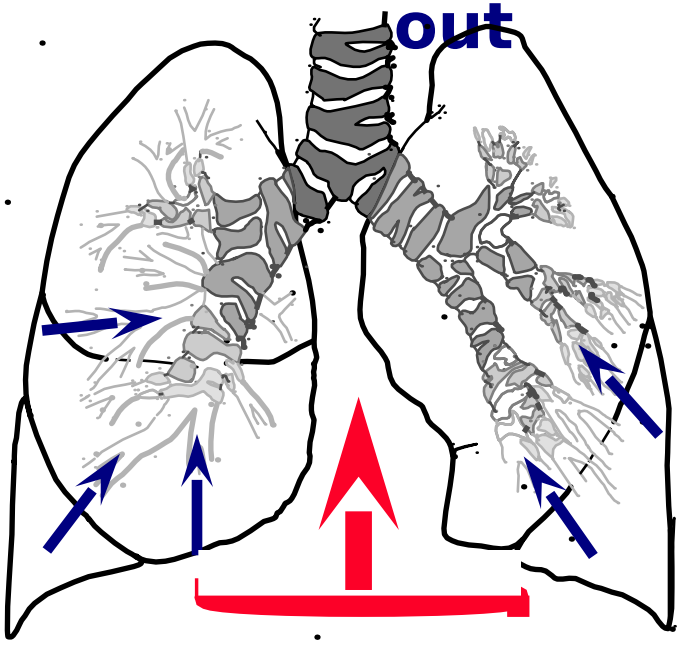
Phases of Respiration

Breathing in



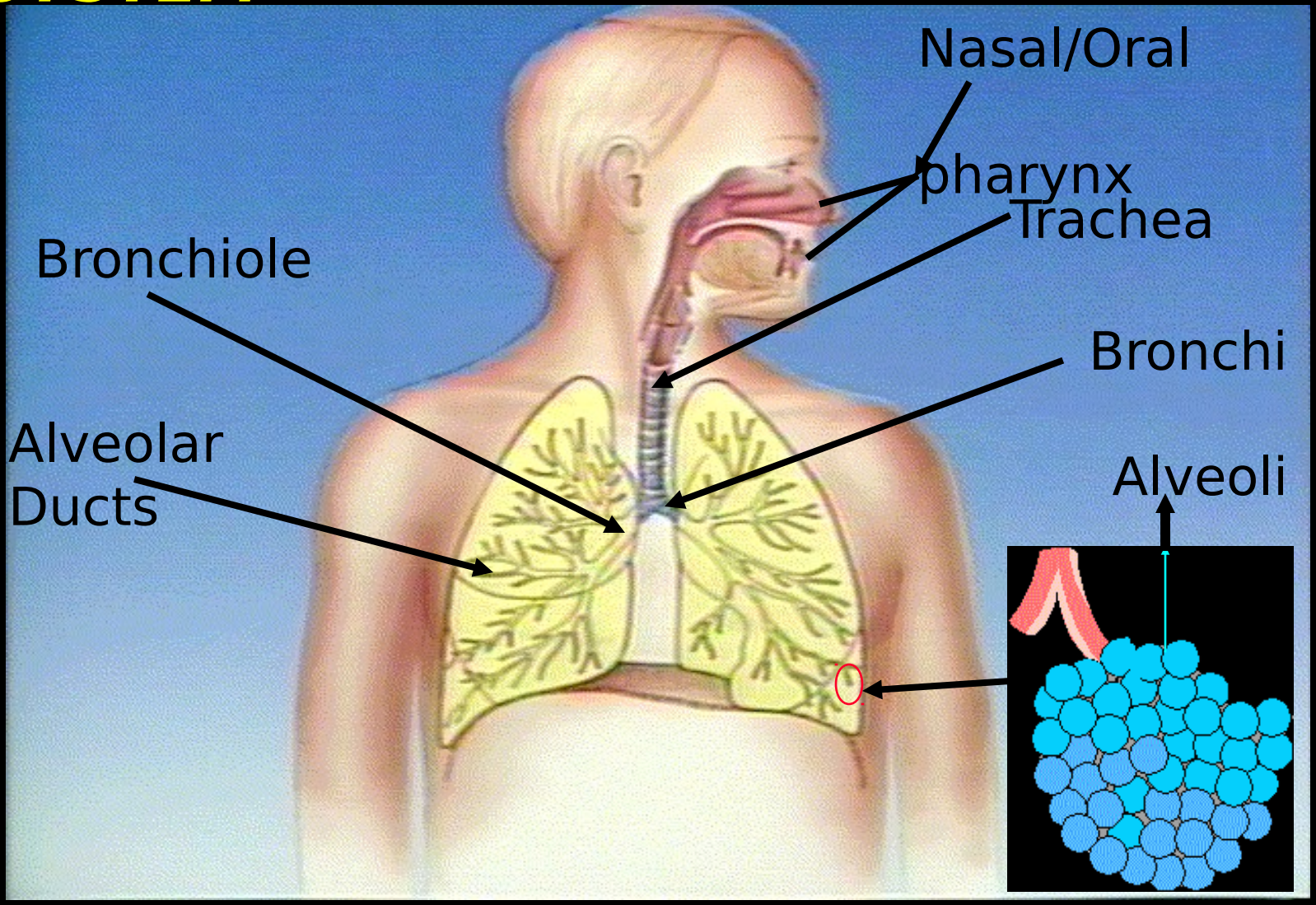
Active Phase
INHALATION

Breathing out



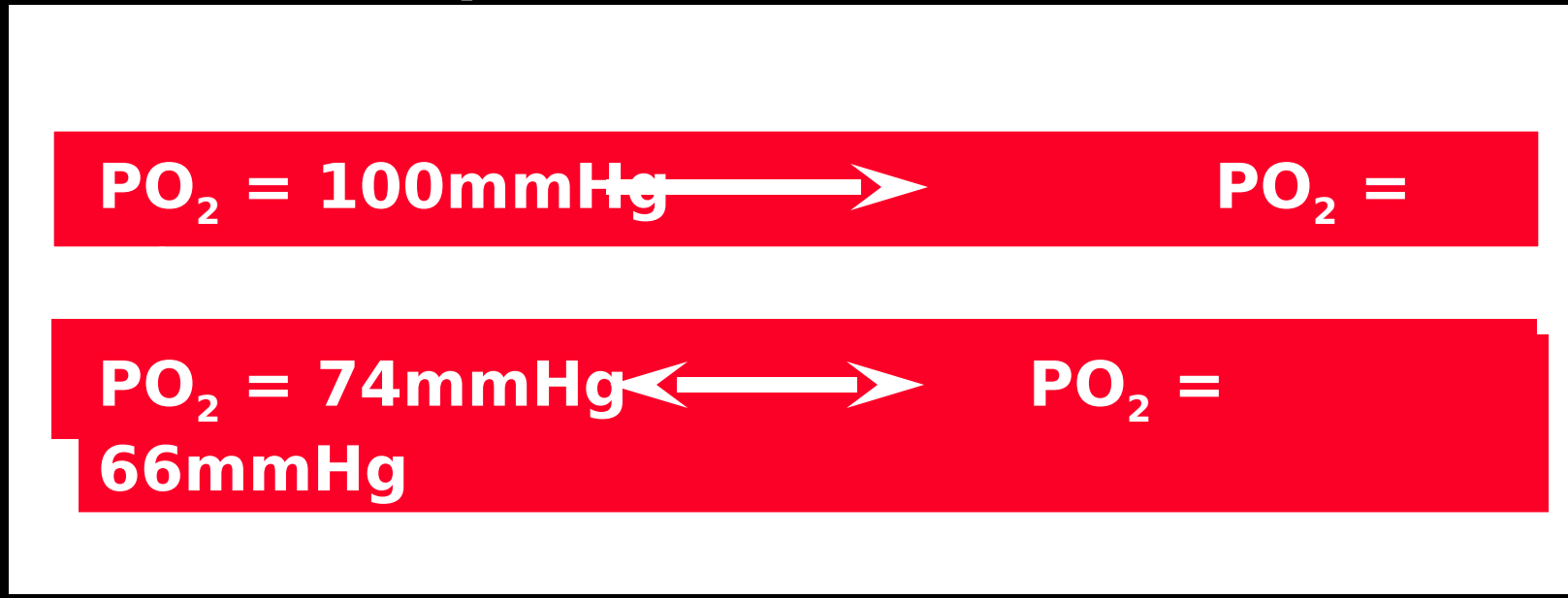
Passive Phase
EXHALATION

COMPONENTS OF THE RESPIRATORY SYSTEM



Law of Gaseous Diffusion

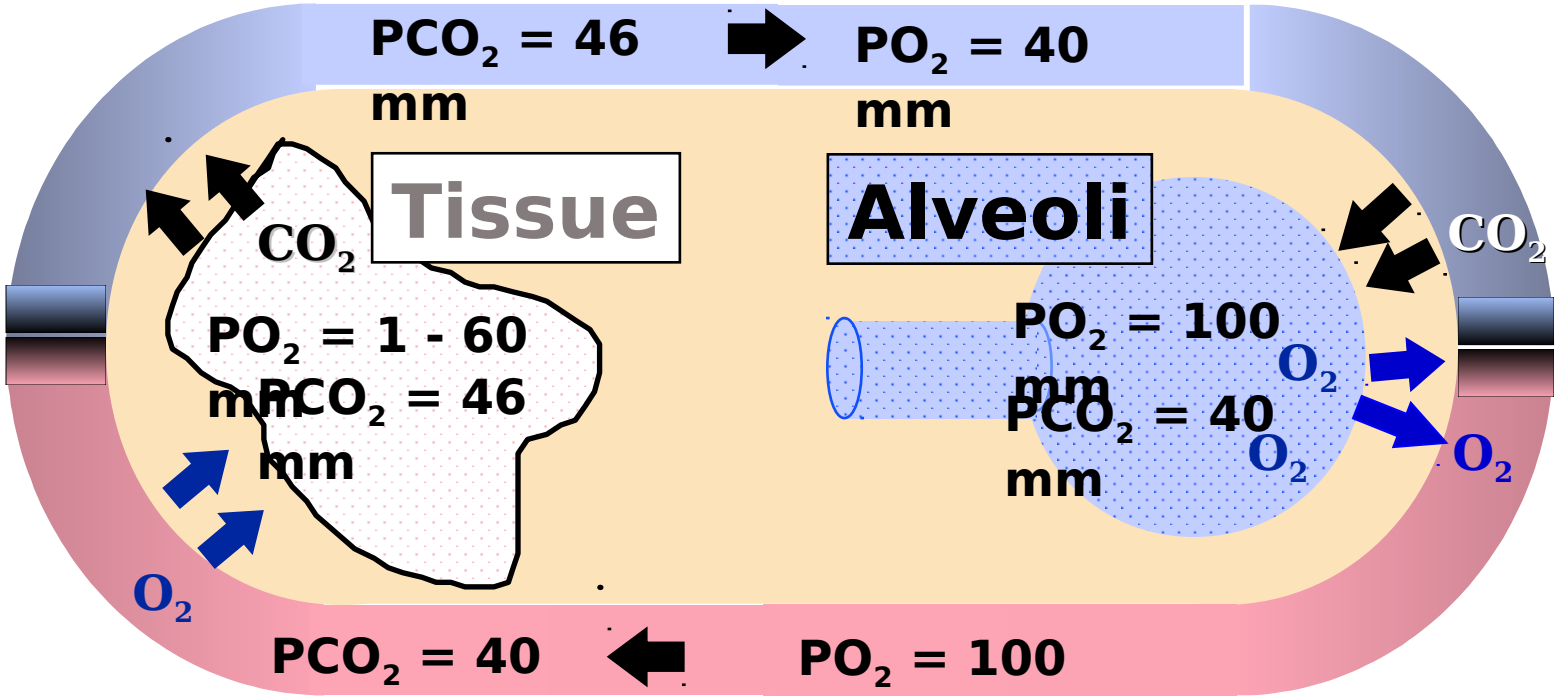
Gas molecules of higher pressure move in the direction of gas molecules of a lower pressure



Blood Gas Exchange

Venous Capillary

Hemoglobin Saturation 75%



Arterial Capillary

Hemoglobin Saturation 98%

Oxygen transport in the blood:

dependent on the partial pressure of oxygen.

pO_2

Correction of Altitude, Alveolar O_2, Hb saturation

-------- *ambient air* --------

ALTITUDE (FEET)	BAROMETRIC PRESSURE (mmHg)	ALVEOLAR OXYGEN (PAO_2)	HEMOGLOBIN SATURATION % (Hb)
Sea level	760	104	97
10,000	523	67	90
20,000	349	40	70
30,000	226	21	20
40,000	141	6	5
50,000	87	1	1

Correction of Altitude, Alveolar O_2, Hb saturation

-------- *100% Oxygen* --------

ALTITUDE (FEET)	BAROMETRIC PRESSURE (mmHg)	ALVEOLAR OXYGEN (PAO_2)	HEMOGLOBIN SATURATION % (Hb)
Sea level		760	673
10,000	523	436	100
20,000	349	262	100
30,000	226	139	99
40,000	141	58	87
50,000	87	16	15

100

Question

Check on learning

#4
- Functions of the respiratory systems
- Phases of the respiratory systems

10 Minutes

Take a break!

ELO #5

- **ACTION**: Match the type of hypoxia with their respective causes.
- **CONDITION**: Given a list of hypoxia types and a list of hypoxia causes.
- **STANDARD**S: IAW FM 3-04.301.

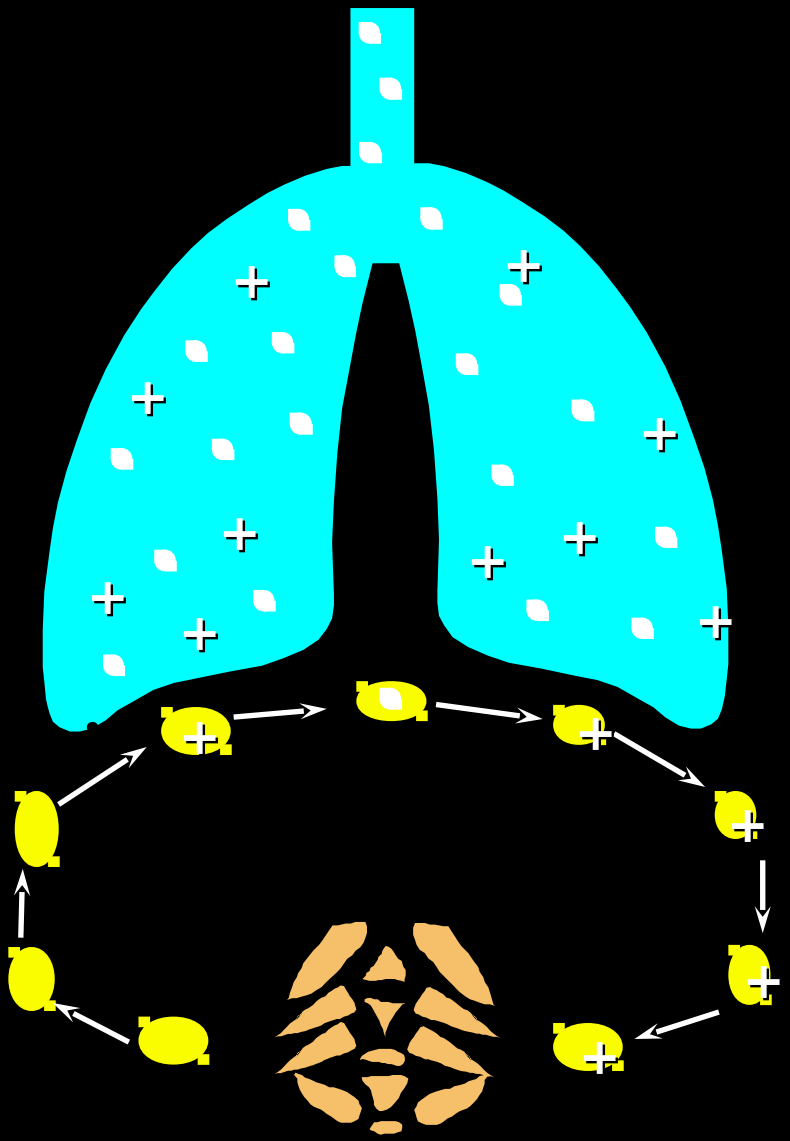
Hypoxia

State of oxygen [O_2] deficiency in the blood cells and tissues sufficient to cause impairment of function.

Types of Hypoxia

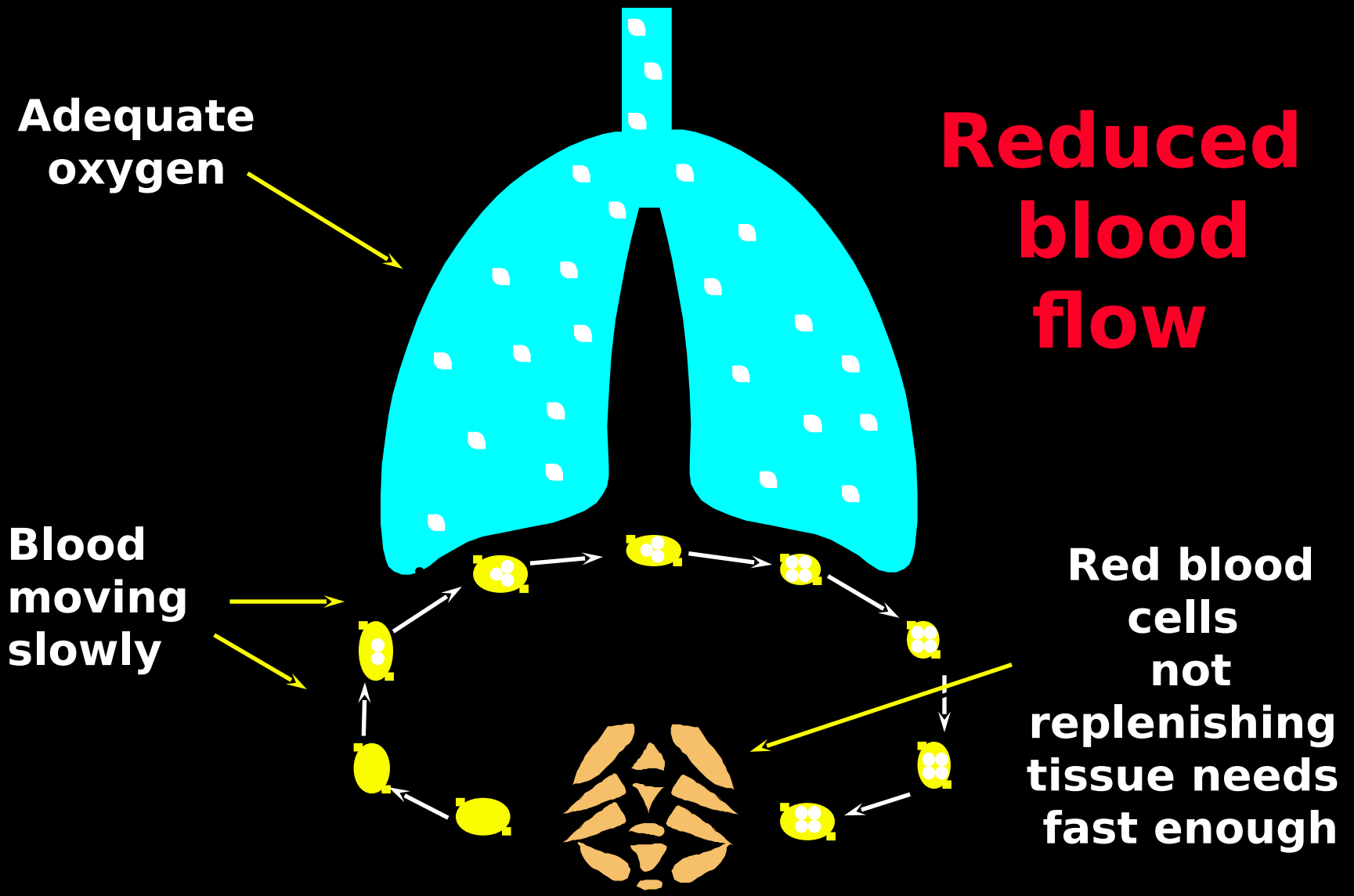
- Hypemic
- Stagnant
- Histotoxic
- Hypoxic

Hypemic Hypoxia

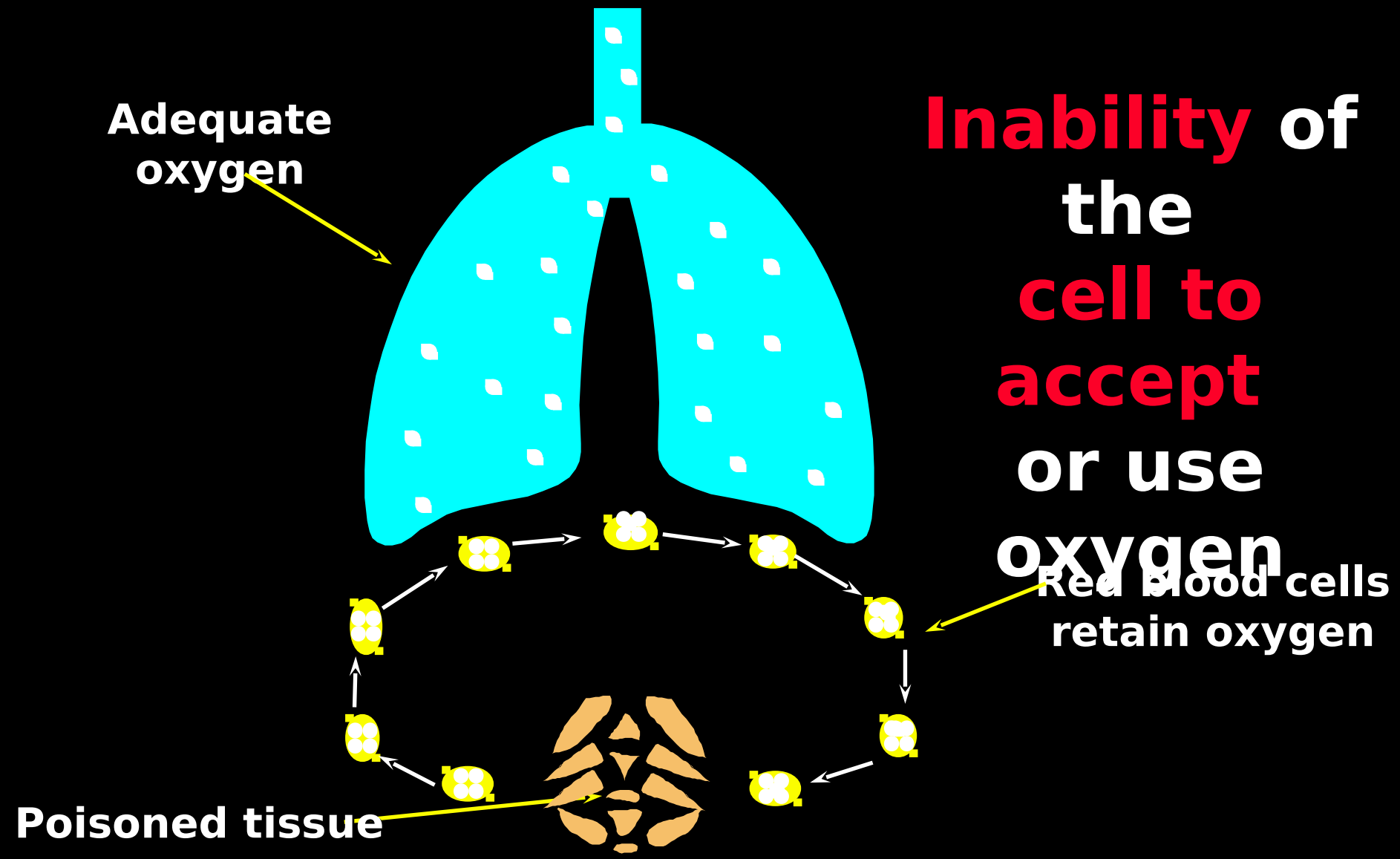


Inability of the blood to accept oxygen in adequate amounts

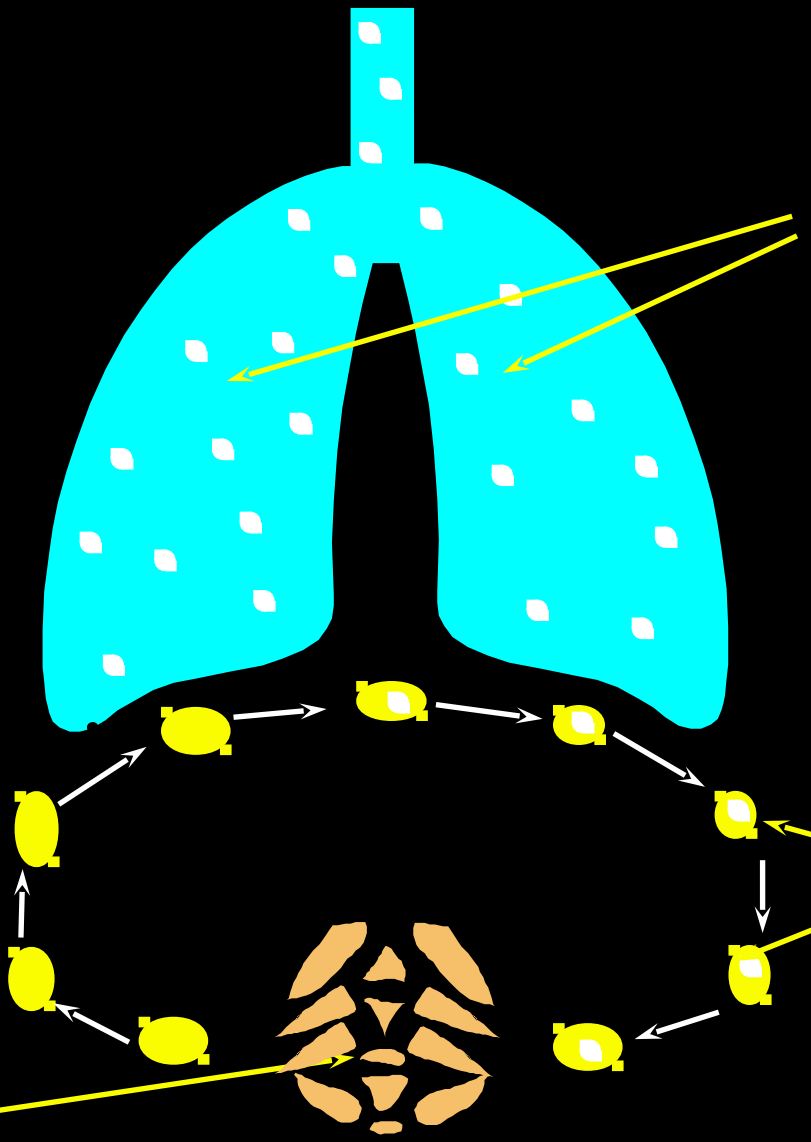
Stagnant Hypoxia



Histotoxic Hypoxia



Hypoxic Hypoxia



Reduced pO_2 in the lungs (high altitude)

Red blood cells

Body tissue

Hypoxia Symptoms what you feel (subjective)

Air hunger

Apprehension

Fatigue

Nausea

Headache

Hot & Cold Flashes

Euphoria

Belligerence

Blurred Vision

Numbness

Hypoxia Signs what we see in you (objective)

- **Hyperventilation**
- **Cyanosis**
- **Mental confusion**
- **Poor Judgment**
- **Lack of muscle coordination**

Stages of Hypoxia

- Indifferent Stage
- Compensatory Stage
- Disturbance Stage
- Critical Stage

Indifferent Stage

- Altitudes:
  - Air: 0 - 10,000 feet
  - 100% O_2: 34,000 - 39,000 feet
- Symptoms: decrease in night vision @ 4000 feet
  - acuity
  - color perception

Compensatory Stage

- Altitudes:

  Air: 10,000 - 15,000 feet

  100% O_2: 39,000 - 42,000 feet

- Symptoms: impaired efficiency, drowsiness, poor judgment and decreased coordination

CAUTION!!!!

Failure to recognize your signs and symptoms may result in an aircraft mishap.

Disturbance Stage

- **Altitudes**

Air: 15,000 - 20,000 FEET

100% O_2: 42,000 - 44,800 FEET

Disturbance Stage

symptoms

- Mental
  - Memory
  - Judgment
  - Reliability
  - Understanding

Disturbance Stage

symptoms

- Personality

- Happy Drunk

versus the

- Mean Drunk

Disturbance Stage

symptoms

- Performance
  - Coordination
  - Flight Control
  - Speech
  - Handwriting

Disturbance Stage

symptoms

- Sensory
  - Vision
  - Touch & pain
  - Hearing

CAUTION!!!!

FAILURE TO RECOGNIZE THESE SIGNS AND SYMPTOMS MAY RESULT IN A AIRCRAFT MISHAP.

Disturbance Stage

- Signs
  - Hyperventilation
  - Cyanosis

Critical Stage

- Altitudes Air: 20,000 feet and above 100% O_2: 44,800 feet and above
- Signs: loss of consciousness, convulsions and death

WARNING!

When hemoglobin saturation falls below

65%

serious cellular dysfunction occurs;

and if prolonged, can cause death

WARNING!

Factors modifying hypoxia symptoms

- Pressure altitude
- Rate of ascent
- Time at altitude
- Temperature
- Physical activity
- Individual factors
- Physical fitness
- Self-imposed stresses

DEATH

- Drugs
- Exhaustion
- Alcohol
- Tobacco
- Hypoglycemia

keep self imposed stresses out of the airc

Expected Performance Times

FL 430 & above	9-12 seconds
FL 400	15 - 20 seconds
FL 350	30 - 60 seconds
FL 300	1 - 2 minutes
FL 280	2 1/2 - 3 minutes
FL 250	3 - 5 minutes
FL 220	8 - 10

Expected performance time for a crew member
flying in a pressurized cabin is reduced approximately one-half following loss of pressurization such
as in a:

RD

Rapid Decompression

Hypoxia

- Prevention
  - Limit time at altitude
  - 100% O_2

Hypoxia

- Treatment
  - 100% O_2
  - Descend to a safe altitude

Questions ????

Check on Learning #5

Hypoxia types/stages

Causes of hypoxia

Signs/Symptoms

- **Treatment of hypoxia**

ELO #6

- **ACTION**: Select the symptoms of hyperventilation.
- **CONDITION**: Given a list.
- **STANDARD**: IAW FM 3-04.301 and Fundamentals of Aerospace Medicine.

Hyperventilation
(*definition)*

An excessive rate and depth of respiration leading to the abnormal loss of CO_2 from the blood.

Hyperventilation (causes)

- Emotional
  - (fear, anxiety, apprehension)
- Pressure breathing
- Hypoxia

Hyperventilation

Symptoms

- tingling sensations
- muscle spasms
- hot and cold sensations
- visual impairment
- dizziness
- unconsciousness

Hyperventilation

reason for symptoms:

- *loss of carbon dioxide [CO_2]*
- *shift in pH balance*

Hyperventilation
significance

- *incapacitation of an otherwise outstanding, healthy air crewmember*
- *confusion with hypoxia*

Hyperventilation
(distinguishing factors)

- above 10,000 feet
  possible hypoxia

- below 10,000 feet
  probably hyperventilation

Hyperventilation (corrective actions)

- ✔ **Don’t Panic**
- ✔ **Control your breathing**

Check your oxygen equipment - it may be hyp

Questions!!!!

Check on Learning #6

- **Hyperventilation**
- **Causes of hyperventilatio**
- **Treatment of hyperventila**

Let’s take

a break

ELO #7

- **ACTION**: Select the causes and treatment of an ear, sinus and tooth trapped gas dysbarism.
- **CONDITION**: Given a list.
- **STANDARD**: IAW FM 3-04.301.

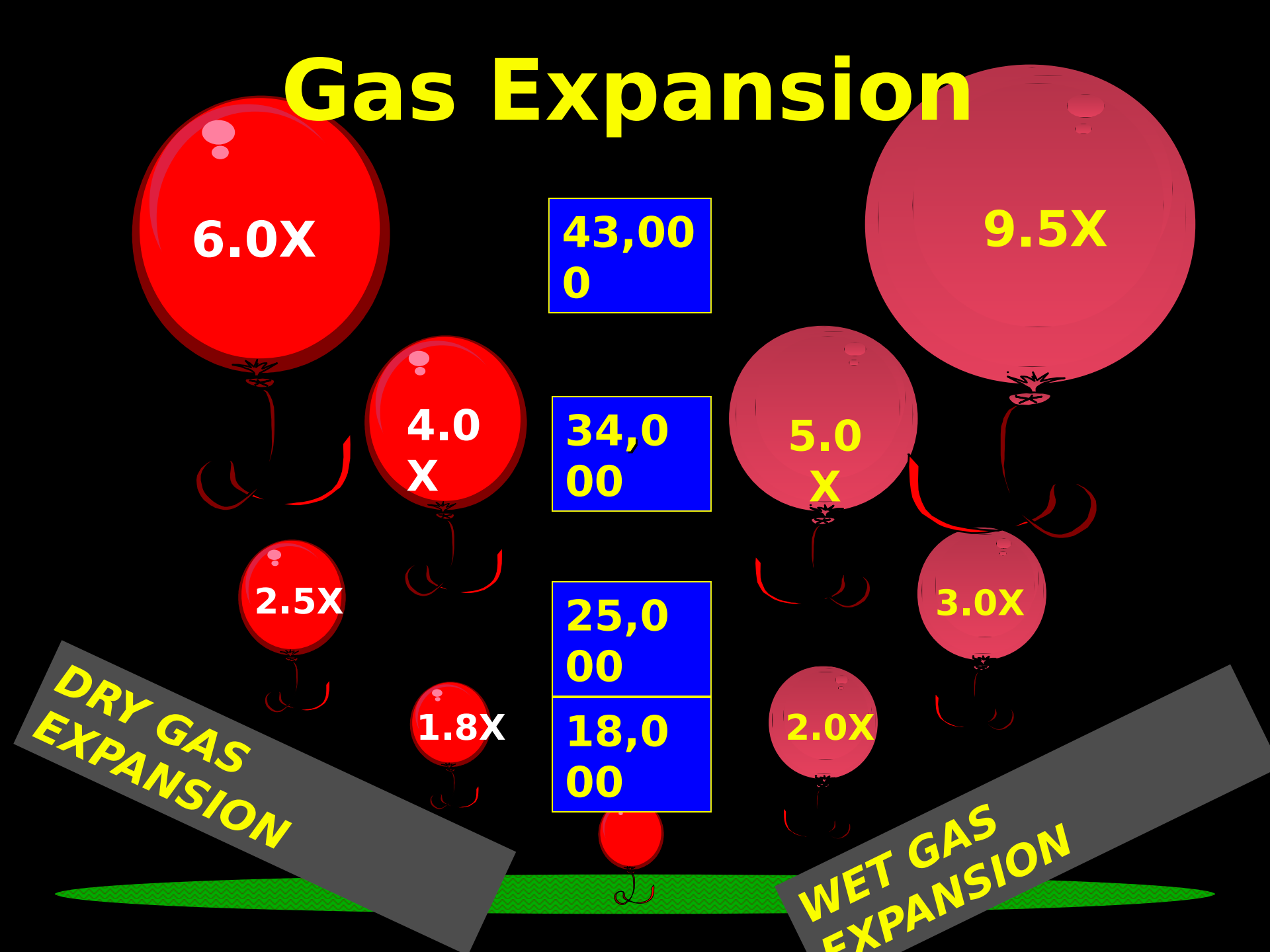
Dysbarism

Syndrome resulting from the effects, excluding hypoxia, of a pressure differential between the ambient barometric pressure and the pressure of gases within the body.

Boyle's Law

The volume of a gas is inversely proportional to its pressure; temperature remaining constant.

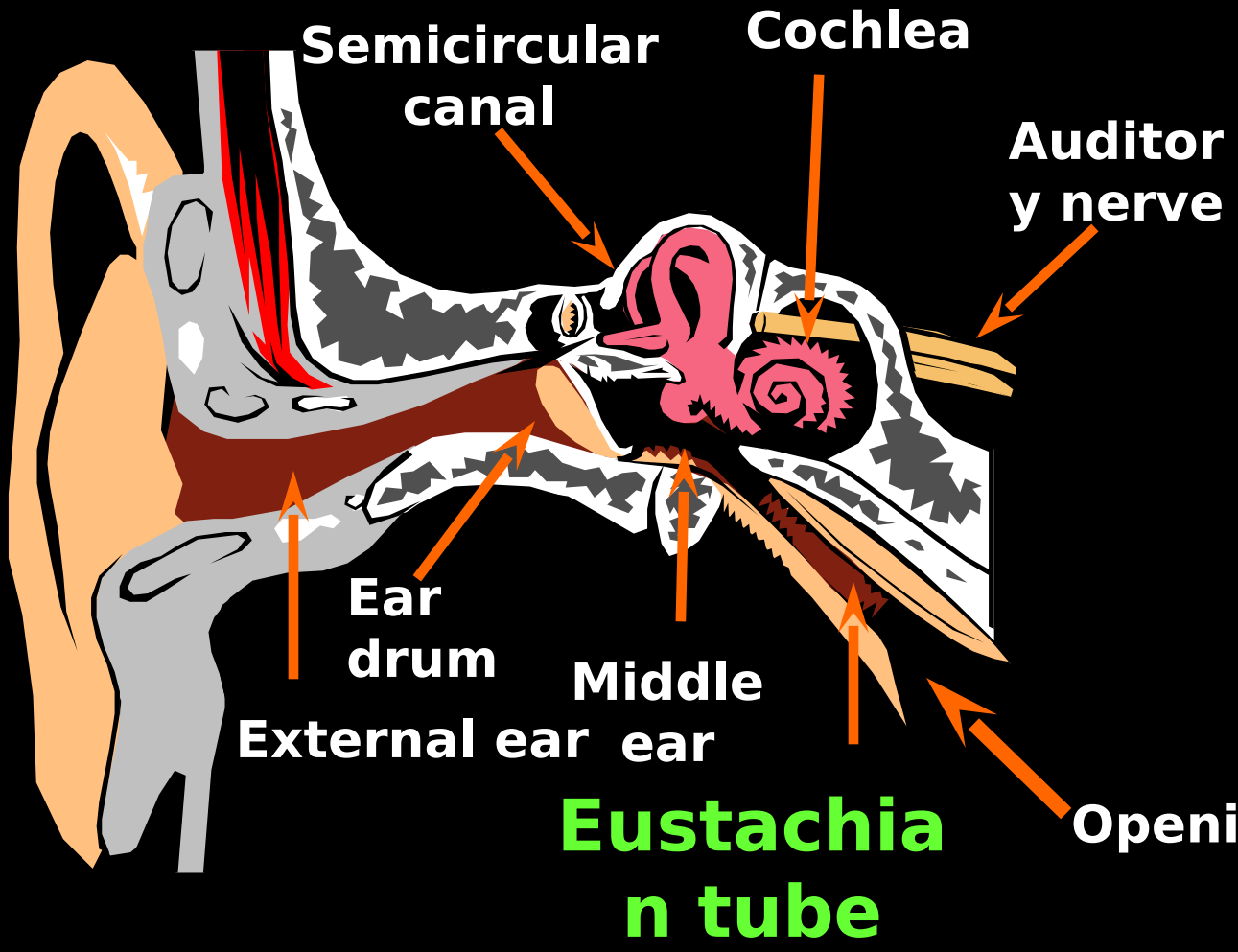
Gas Expansion



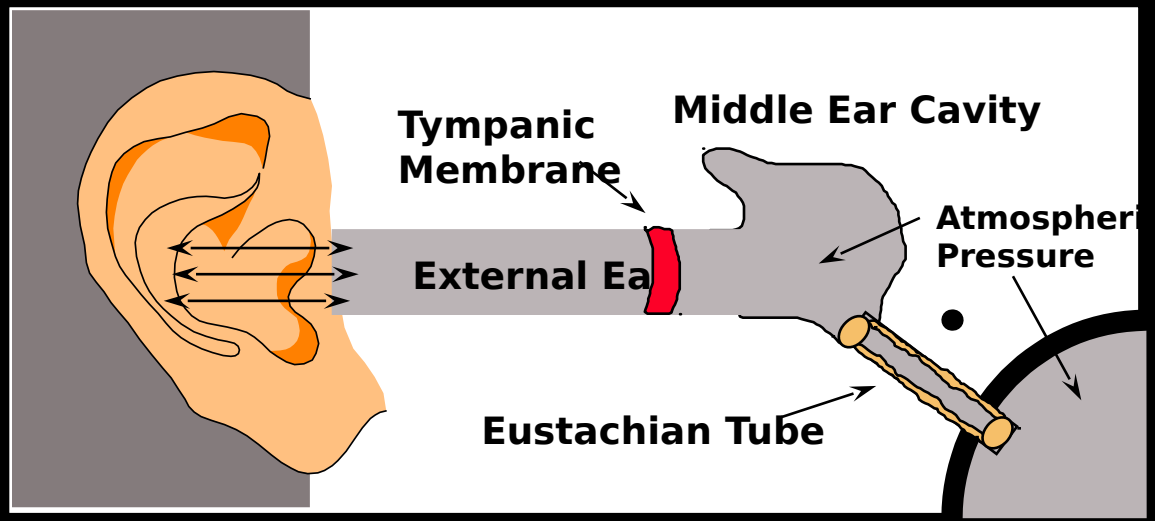
Gas Expansion (prevention of gas pain)

- Watch your diet, don’t eat too fast
- Avoid soda and large amounts of water just prior to going to altitude
- Don’t chew gum during ascent
- Keep regular bowel habits; eat your fiber

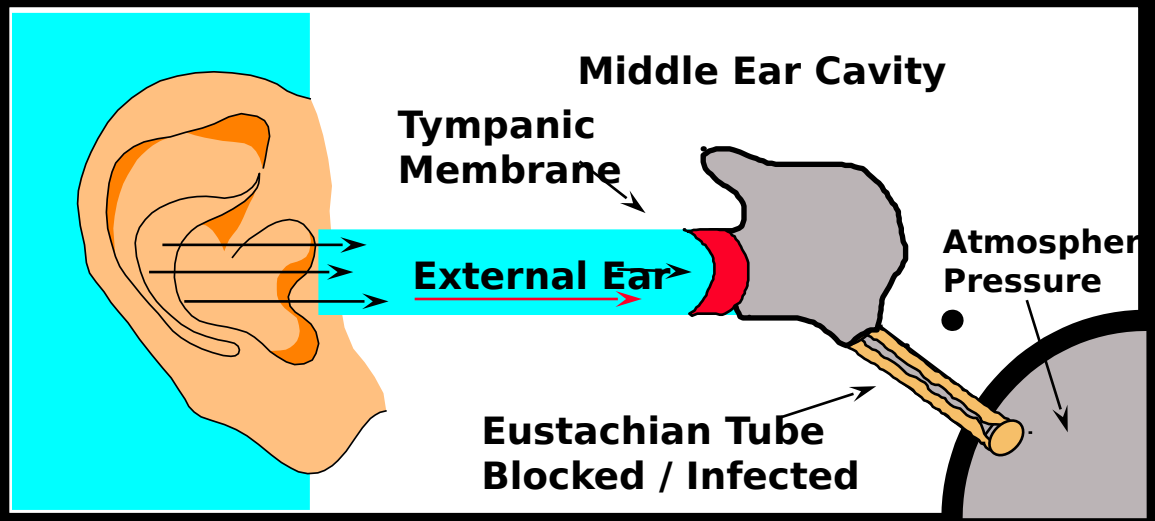
Anatomy of the Ear



Pressure Effect

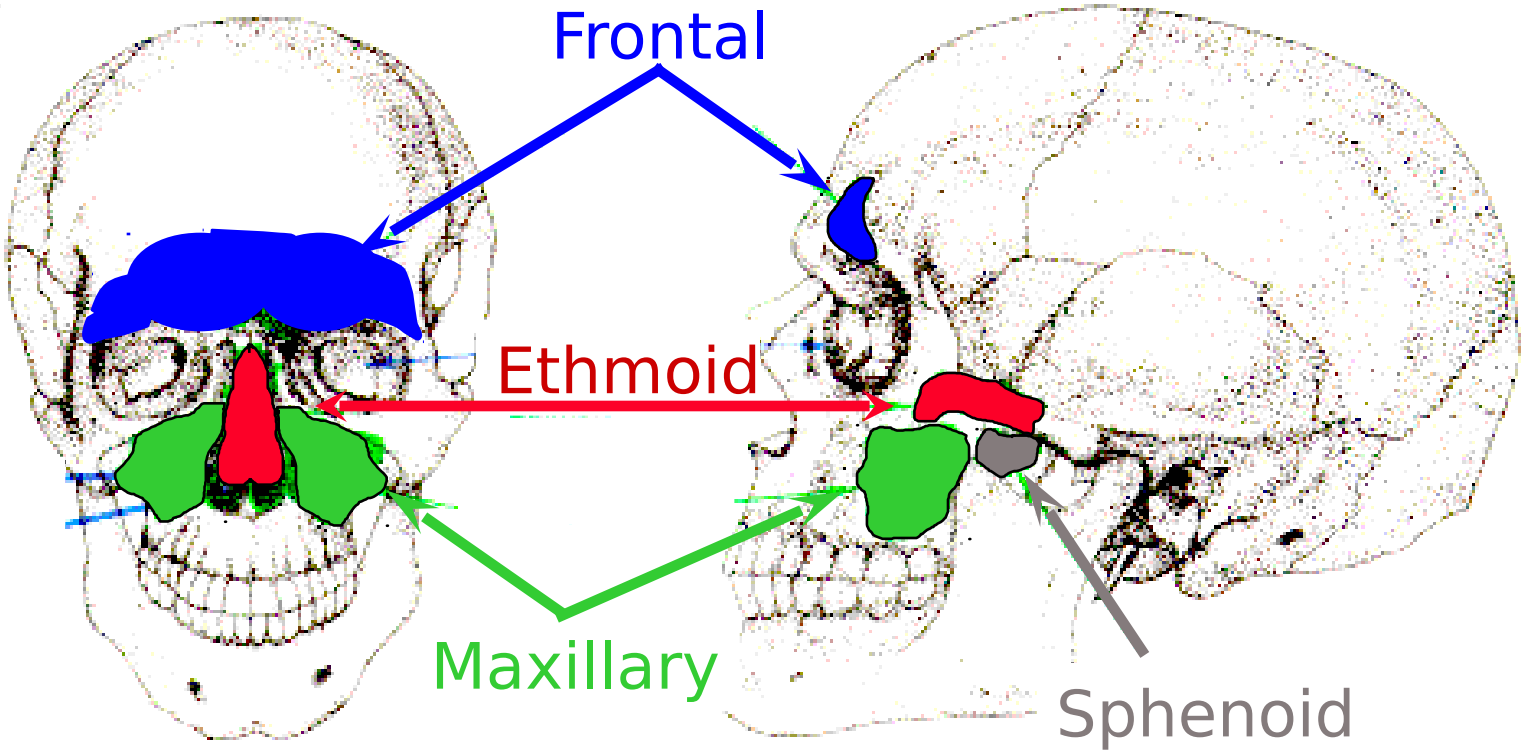


Clear



Ear Block

The Sinuses



Treatment of an Sinus/Ear Block

- Stop the descent of the aircraft and attempt to clear by valsalva.
- If unable to clear, climb back to altitude until clear by pressure or valsalva.

- Descend slowly and clear ear frequently during descent.

Barodontalgia

- Tooth pain due to:
  - Gum abscess: dull pain on ascent
  - Inflamed pulp: sharp pain on ascent
  - Inflamed maxillary sinus: pain primarily on descent

TREATMENT of Barodontaliga

- Descend aircraft/chamber to sea level.
- Seek dental help

Questions

Check on Learning #7

- **Trapped gas dysbarism**
- **Treatment of ear and sin**
  dysbarisms
- **Treatment of tooth pain**

ELO #8

- ACTION: Identify the types and treatments of evolved gas dysbarsims, which occurs with altitude.
- CONDITIONS: Given a list.
- STANDARD: IAW FM 3-04.301 and Fundamentals of Aerospace Medicine

Decompression Sickness (evolved gas dysbarism)

Results due to the reduction in atmospheric pressure. As pressure decreases, gases dissolved in body fluids are released as bubbles.

Henry's Law

- The amount of gas dissolved in solution is directly proportional to the pressure of the gas over the solution.

Evolved gas disorders are considered serious and medical treatment and advice must be sought immediately.

Evolved Gas Disorders

- The Bends
- Paresthesia
- The Chokes
- Central Nervous System-CNS

Evolved Gas Disorders

- **The Bends**
  - N2 bubbles become trapped in the joints. Onset is mild, but eventually painful!

Evolved Gas Disorders

- **Paresthesia**
- N2 bubbles form along nerve tracts. Tingling and itchy sensation and possibly a mottled red rash.

Evolved Gas Disorders

- **The Chokes**
  - N2 bubbles block smaller pulmonary vessels. Burning sensation in sternum. Uncontrollable desire to cough. Sense of suffocation ensues.

Evolved Gas Disorders

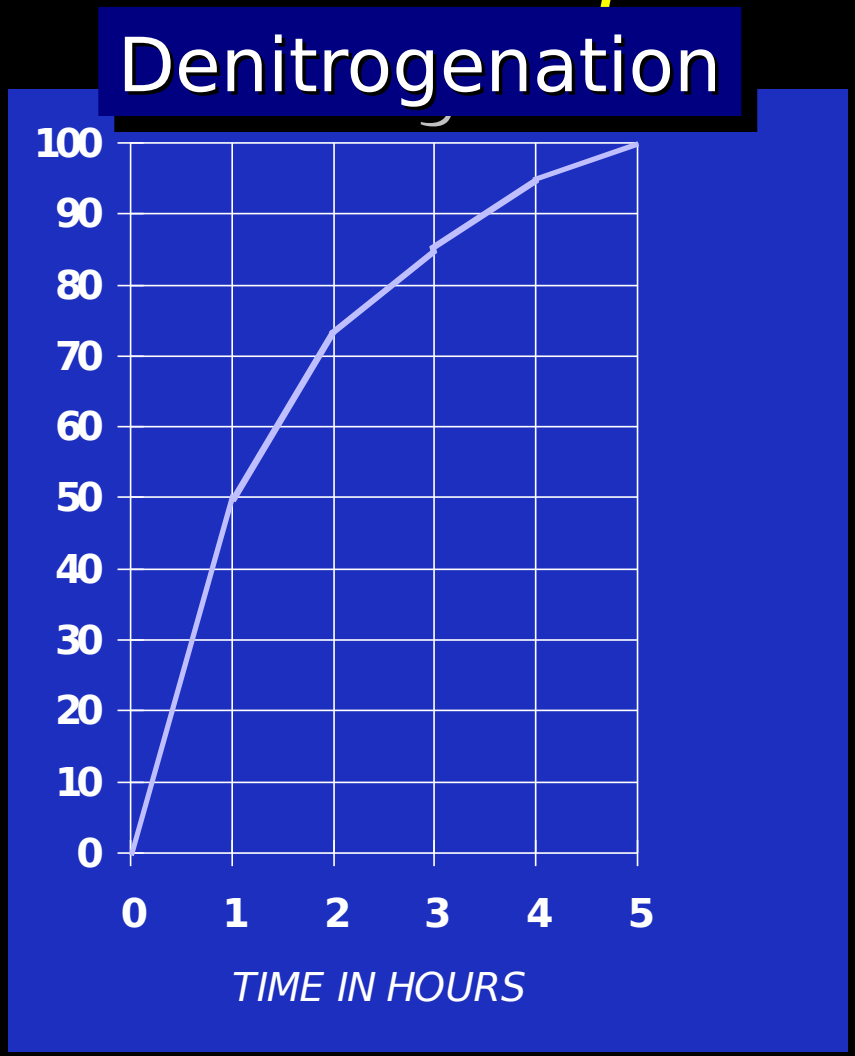
- **CNS**
- N2 bubbles affect spinal cord. Visual disturbances, paralysis, one sided tingling.

Evolved gas factors

- Rate of ascent
- Altitude
- Body fat content
- Age
- Exercise
- Duration of exposure
- Repeated exposure

Decompression Sickness

prevention



- Denitrogenation
- Maintain cabin pressurization

Decompression Sickness

treatment

- Descend
- 100% Oxygen
- Land at nearest location where qualified medical assistance is available.
- Compression greater than 1 atmosphere (absolute).

Scuba Divers Beware!

24 Hour restriction

between diving and flying!!!!!

QUESTIONS

Check on Learning #8

- **Evolved gas dysbarism**
- **Four types of DCS**
- **Treatment**

CONCLUSION